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Breeding of the Seychelles Magpie Robin *Copsychus sechellarum* and implications for its conservation

JAN KOMDEUR
BirdLife International, Wellbrook Court, Girton Road, Cambridge CB3 ONA, UK
National Environmental Research Institute, Department of Wildlife Ecology, Kalø, Grenåvej 12, DK-8410 Rønde, Denmark
Zoological Laboratory, University of Groningen, PO Box 14, 9750 AA Haren, The Netherlands

The total population of the Seychelles Magpie Robin *Copsychus sechellarum* declined from 38–41 birds in 12–13 territories in 1977–1978 to 17–21 birds in eight to nine territories in 1988–1990 and was entirely confined to Fregate Island (210 ha) in the Seychelles. After a successful cat eradication program in 1981–1982, recruitment improved, although the abandonment of agriculture had caused a reduction in the amount of feeding habitat and hence in the carrying capacity of the island. The population declined because of the failure of recruitment to compensate for the annual adult mortality. Foraging activity of the Magpie Robin was greater in high-quality territories (measured by soil invertebrates available), leading to increased reproductive success. Through supplementary feeding, five times as many recruits were produced. Of the 11.5 potential annual breeding recruits, 5.3 are required to compensate for adult mortality, and the other 6.2 recruits can be regarded as "surplus" contributing to an increase. Magpie Robins prefer to breed in rotten trees, which are a scarce resource. The greater the distance between the nest site and feeding areas, the less time was spent in incubation and nest guarding, resulting in greater egg loss. Because of lack of suitable areas for establishing territories, many young Magpie Robins became "floaters". Nest disturbance, both by these floaters and by the introduced Indian Mynah *Acridotheres tristis*, had adverse effects on the breeding success of robins. A recovery plan has been designed to save the Magpie Robin. Territories have been improved for feeding (by tree planting) and for breeding (by providing nestboxes and reducing nest disturbances). Given the vulnerability of one small island, the presence of surplus birds (supported mainly by supplementary food) and the suitability of neighbouring Aride Island (68 ha), successful translocations to this island took place in 1992 and 1994. Given the presence now of 47 individuals on two islands, it is hoped that the species will pull back from the brink of extinction.

The islands of the western Indian Ocean support 26 threatened bird taxa listed in the *ICBP/IUCN Bird Red Data Book* and include some of the smallest and most threatened bird populations in the world (Collar & Stuart 1985). In the central Seychelles group, eight taxa are threatened. One of these, the Seychelles Magpie Robin *Copsychus sechellarum*, was reduced to a population entirely confined to Fregate Island (210 ha) (Fig. 1). Since the arrival of the first permanent human settlers in 1770, introduced mammalian predators (Domestic Cats *Felis catus* and rats *Rattus* spp.) have become established, and all of the natural vegetation has been cleared to grow a variety of crops and secondary woodland. The Magpie Robin is particularly vulnerable to mammalian predators because it is tame, forages mostly on the ground, and the noisy young leave the nest before they are capable of strong flight. It is believed that the introduced predators and habitat loss were principally responsible for the contraction in range of the robin population from eight islands (the named islands in Fig. 1; Wilson & Wilson 1978) to one island. Since 1960, a self-sustaining population existed only on Fregate, which has never been colonized by rats. However, Cows *Bos domesticus*, free range Domestic Pigs *Sus domesticus*, Domestic Hens *Gallus gallus*, Giant Tortoises *Geochelone gigantea* and Indian Mynahs *Acridotheres tristis* (introduced to Seychelles in the early 19th century; Penny 1982) are present.

The International Council for Bird Preservation (ICBP; now BirdLife International) has monitored the Magpie Robin

* Present address: Zoological Laboratory, University of Groningen, PO Box 14,9750 AA Haren, The Netherlands.

Plate 1. Adult Seychelles Magpie Robin on Aride Island (photograph by Lars Gabrielsen).

population at regular intervals since 1967. In 1977–1978, the total population varied between 38 and 41 birds in 12 to 13 territories (Watson *et al.* 1992; Fig. 2). Its distribution was largely restricted by the feeding habitat of bare earth and leaf litter, which occurred under mature, shady woodland and in cultivated vegetable gardens (Watson *et al.* 1992). Six birds were reintroduced to Aride Island (68 ha; Fig. 1) in April 1978 and a further four in April 1979, and there have been at least five breeding attempts since, although only one resulted in a fledged chick, which did not survive (Watson *et al.* 1992). In 1980, only one male from the 1978 introduction was present, and it survived until 1988 (I.D. Bullock, pers. comm.) In 1978 and 1979 it was suspected that chemicals used for pest control in houses and vegetable gardens were a risk to Magpie Robins (Watson *et al.* 1992). Another reason for the failure may have been the exceptionally dry weather immediately following the transfer in 1979 (J. Watson, pers. comm.), which might have caused a decline in soil invertebrates, the main food source for the robins. New translocations had to be abandoned because of the declining population on Fregate in 1980. By 1981, only 24 birds were present on Fregate with virtually no recruitment, and an increase in the feral Cat population was implicated (Fig. 3). A successful cat eradication program by ICBP and the New Zealand Wildlife Service in 1981–1982 improved subsequent recruitment, but the population has not returned to its original level (Fig. 3). In the meantime, more woodland had been cleared to make way for coconut plantations, and agriculture had declined drastically (the number of plantation workers fell from a peak of 118 in 1947 to 15 in 1980). This has resulted in fewer rotten trees with holes, which are preferred for nesting, and in a decline in quality and extent of foraging habitat within existing territories, caused by a rapid growth of a rich her-

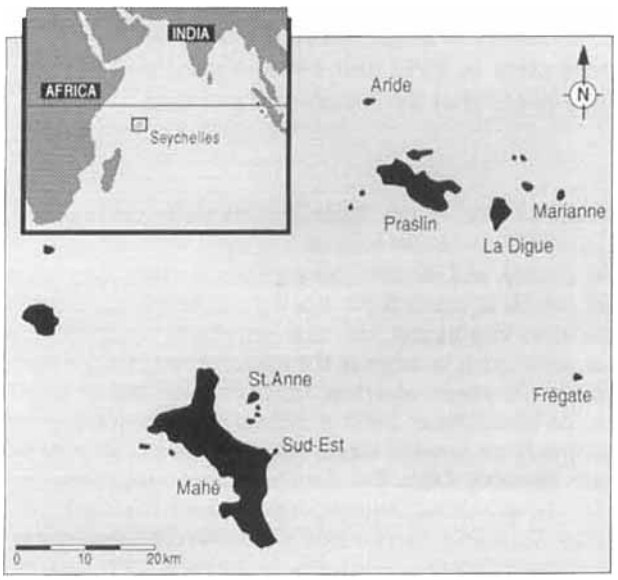

Figure 1. Map of the Seychelles. There are historical records of Magpie Robins from the named islands (Collar & Stuart 1985), although the species survived only on Fregate.

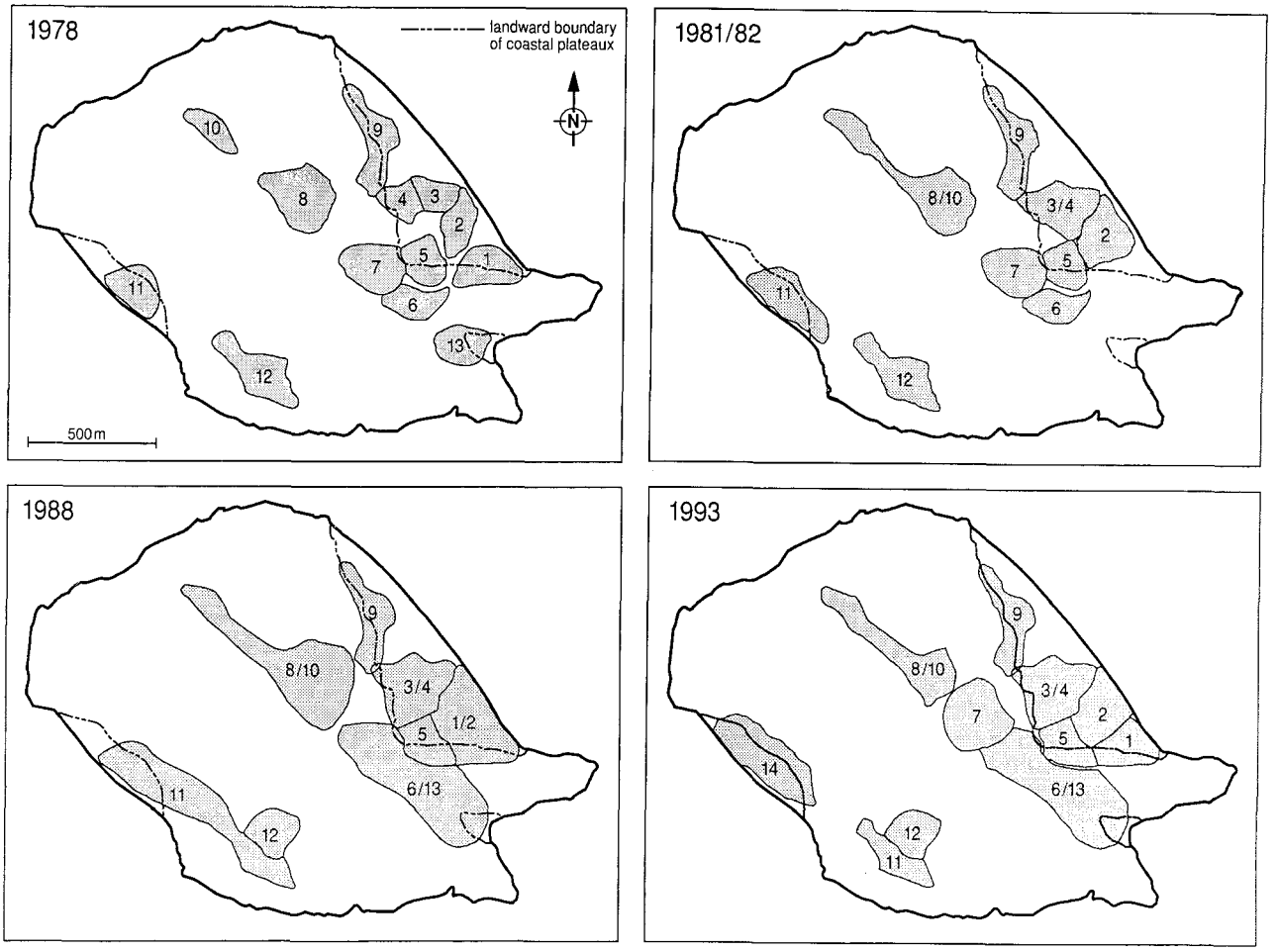

Figure 2. The locations of Magpie Robin territories on Fregate Island in 1978 (Watson 1978), 1981 (Todd 1982), 1988 (this study) and 1993 (McCulloch 1994). Figures refer to territories in the text.

baceous cover. As a result, the carrying capacity of the island has been reduced. Some birds expelled others from adjacent territories to obtain an adequate foraging area, while others were unable to establish new territories because of a lack of suitable areas. This resulted in fewer but larger territories (Fig. 2).

Throughout the last decade, the population has oscillated around a dangerously low number of between 20 and 26 birds. Surveys found only 23 birds present in eight territories in 1987 and in 1988 (J. Komdeur, unpubl.). Until then, almost nothing was known about the ecology of the Seychelles Magpie Robin, and ICBP concluded that further efforts were needed to ensure the survival of the species. Since then, a 2-year research program on the Magpie Robin has been carried out to gather ecological data and to identify precisely the limiting factors as a basis of a recovery plan. In this paper, I present studies of the ecology of the Magpie Robin from June 1988 to September 1990, and I compare the results with earlier findings from 1977–1978 (Watson *et al.* 1992) and 1981–1982 (Todd 1982). I will use a supplementary feeding experiment to show the importance of food availability on reproductive performance of Magpie Robins. Based on the conclusions of these studies, I present the recovery plan and its outcome, which included the establishment of the Magpie Robin on Aride Island.

METHODS

Data collection

All Magpie Robins were individually colour-ringed. The entire population was counted weekly, sometimes with the help of playback recordings of song. The precise locations of all individuals were recorded throughout the study period.

For each robin, monthly foraging observations were made for five 1-h periods in periods equally spaced over the day: 06.30–09.00 h, 09.00–11.30 h, 11.30–14.00 h, 14.00–16.30 h, and 16.30–19.00 h. For each territory, a map with an overlaying 25-m × 25-m grid was used. The following were noted at 30-s intervals: the height of the bird above ground level, the vegetation type (Komdeur *et al.* 1989) and grid number in which the bird was present, the presence of

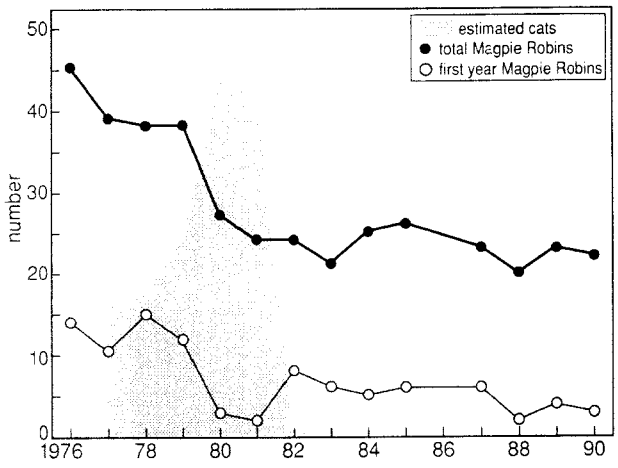

Figure 3. Number of feral Cats and Magpie Robins (first-year birds and total number of birds) on Fregate Island (sources for data in different years: 1976: Wilson & Wilson [1978]; 1977, 1978: Watson *et al.* [1992], Todd [1982]; 1979: Watson & Trowbridge [1979]; 1980–1982: Todd [1982]; 1983: Watson [1983]; 1984: V. Laboudallon [unpubl.]; 1985: A. Seddon & M. Garnet [unpubl.]; 1987: J. Komdeur [unpubl.]; 1988–1990: this study).

plantation workers, Cows, Domestic Pigs, Giant Tortoises, or Domestic Hens within 2.5 m from the bird and whether or not foraging was taking place. During foraging, the first prey item taken, number of pecks and the number of successful and unsuccessful pecks were recorded during the 30-s interval. Part of the method was similar to that used by Watson *et al.* (1992) during 1977–1978, in order to provide comparable data. The robins were remarkably tame and were observed from within a few metres, which enabled the scoring of prey types. Prey items were classified into the following groups: worms, centipedes (>1 cm), millipedes (>1 cm), spiders (>0.5 cm), insects (>0.5 cm), skinks (*Mabuya* sp.), geckos (*Phelsuma astriata* and *Aeluronyx sechellensis*) and fruits. A successful peck was one after which the bird was seen swallowing food. Foraging success was expressed as the mean number of successful pecks per 30 s, foraging activity as the product of feeding rate per 30 s and percentage time spent foraging and foraging efficiency as the product of foraging success and percentage time spent foraging. In all territories, each 25-m × 25-m grid was checked weekly to assess the number of plantation workers, domestic animals and Indian Mynahs.

To test whether territory quality affected foraging activity, intensive foraging studies were conducted in August and September 1989 on nonmoulting and nonbreeding adult robin pairs in eight territories (10-h observation period per bird per month). To determine whether Magpie Robins competed for food with free-range Domestic Hens and Indian Mynahs, foraging studies on these species were conducted at the same time on the eastern area of Fregate Island.

During the whole study period, all territories were checked fortnightly for active nests and each active nest was examined daily. Observations on nest building were conducted in the second week after nest initiations. Observations on incubating and nest guarding (when the bird was less than 2.5 m from the nest) were conducted in the second week after egg laying. Food provisioning observations started 2 weeks after hatching and were repeated every 3 weeks until the young died or reached independence. Each observation period comprised 5 h: 2.5 h in the morning and 2.5 h in the afternoon. Every 30 s, I recorded whether a bird was engaged in any of the behaviours mentioned. Total percentage of time near or on the nest was expressed as the sum of the percentage of time incubating and nest guarding, minus the percentage of time simultaneously incubating by the female and nest guarding by the male. Total food provision frequency was calculated as the sum of the mean food provision rates for each 3-week period throughout the period of dependence.

The importance of territory quality on reproductive success was determined by correlating average territory quality with the mean breeding performance from June 1988 to December 1989, during which period no supplementary feeding had taken place. In the comparison of the birds' foraging activity and their reproductive output in 1977–1978, 1981–1982 and 1988–1990, only those territories which had not significantly changed in area and number of birds present (nos. 3/4, 5, 9, 11 and 12; Fig. 2) were included.

Unless otherwise stated, means are expressed with standard errors or with 95% confidence limits (for percentages). The null hypothesis is rejected at $P < 0.05$.

Territory and island quality

Territory and island quality could be measured in terms of density of predators or food availability. Adult Seychelles Magpie Robins lack natural predators. Potential nest predators are two species of endemic snakes, *Lycognathophis seychellensis* and *Boaedon geometricus*, skinks and geckos, all of which were evenly distributed over the island (Komdeur *et al.* 1989). The robins feed mainly on invertebrates, 96% of which are taken from herb-free areas of leaf litter and bare earth. Therefore, territory and island quality depend on the density of invertebrate prey in litter and soil, which varies with vegetation type and cover of vegetation type. In addition, territory quality also depends on size of the territory. In a large territory with many low-quality areas, which provides as much food as a small territory with few high-quality areas, it is expected that the robins feed at a lower rate and have to visit more places. Territory quality (t) was therefore expressed as mean number of prey invertebrates available per unit area and island quality (iq) as total number of prey invertebrates present, using the following equations:

$$t = \left(\sum_{i=1}^{15} (s_i * p_i)\right) \Big/ s \qquad iq = \sum_{i=1}^{15} (s_i * p_i),$$

where s_i is the mean yearly number of 25-m × 25-m squares of vegetation type i, present in a territory or on the

island, p_i is the mean of the monthly prey totals inhabiting the leaf litter and the upper 5 cm of the soil under vegetation type i per surface area (133 cm^2) and s is total number of 25-m × 25-m squares present in a territory.

For a quantitative assessment of variation in food abundance in the leaf litter and soil under different vegetation types and within a certain period, each month (between days 15 and 20) prey availability, p_i, had been assessed on Fregate Island during the study period and simultaneously on Aride Island from May 1989 to April 1990. On Fregate, prey sampling took place at 35 sites, both in and outside territories, and on Aride at 11 sites, consisting of all vegetation types present on the islands (Komdeur *et al.* 1989). At each site, seven samples were taken using a tube of 12.5 cm in diameter (133 cm^2). Prey items were counted and classified into the same groups as described above. For both islands, detailed maps of vegetation types were prepared using aerial photographs (1:5000).

Similarity in feeding ecology among landbird species on Aride Island

Between September 1987 and March 1988, the feeding ecology of all six landbird species inhabiting Aride Island was studied: the Barred Ground Dove *Geopelia striata*, Turtle Dove *Streptopelia picturata*, Madagascar Fody *Foudia madagascariensis*, the endemic Seychelles Sunbird *Nectarinia dussumieri* and the single Seychelles Magpie Robin present. At that time, the endemic Seychelles Warbler *Acrocephalus sechellensis* had not been introduced to the island (Komdeur 1994).

Once a month, a fixed transect (1.5 km) was walked through the Magpie Robin territory, once in the morning (06.00–08.30 h) and once in the afternoon (16.30–19.00 h), stopping for 2-min periods at 30 points, each 50 m apart. All instances of feeding activity by landbirds that appeared to involve prey capture were recorded; searching behaviour was not included. At every 30 s (with no more than four observations per bird), the following observations were made: feeding height: 0 m (ground), 0.01–4.0 m, 4.1–8.0 m, >8.0 m; plant species under or in which the bird was found foraging: Morinda *Morinda citrifolia*, Pisonia *Pisonia grandis*, other trees, herbs; part of the plant involved: branch, leaf, flower, fruit; food item taken: insect, soil invertebrates, fruit/seed, nectar. Because the birds were remarkably tame, direct observations to score types of food item taken were possible. The similarity in feeding ecology between pairs of bird species was calculated as the sum of the least shared percentage in each feeding category (Appendix; see Komdeur 1994). The overlap between bird species i and j (O_{ij}) was calculated as the sum of the least shared percentage (P_{min}) in each feeding category. For example, the sum of the least shared percentages for feeding observations of the Barred Ground Dove and the Turtle Dove is 0.0% + 31.5% + 0.0% + 0.0% + 41.4% + 0.0% + 0.0% + 0.0% + 0.0% = 72.9%. The extent of similarities is illustrated by means of a phenogram, using the unweighted pair-group method using arithmetic averages (see Komdeur 1994).

Supplementary feeding experiment

In January 1990, nine territories of Magpie Robins were separated into groups of five experimental (nos. 1/2, 3/4, 9, 11 and 12) and four control units (nos. 5, 6/13, 8/10 and 14) (Fig. 2). From January to August 1990, supplementary food was provided to the experimental units twice a week. The main supplement consisted of 20–25 freshly killed cockroaches, grated coconuts, boiled rice and fish, all of which was rapidly taken by the birds. In addition, an area of 4 m^2 of soil was broken up in order to provide access to prey items (e.g. worms and beetle larvae). Field observations suggested that the total amount provided was unlikely to exceed 40% by weight of a bird's daily food requirement. The reproductive success of each breeding pair was assessed during the period of supplementary feeding and during a corresponding period without supplementary feeding (January–August 1989).

Mean monthly territory quality (±s.d.) was the same for experimental (n = 5) and control territories (n = 4) during the 8-month period without (1.48 ± 0.35 *v* 1.82 ± 0.14; t_7 = 2.17, n.s.) and with supplementary feeding (1.60 ± 0.29 *v* 1.61 ± 0.09; t_7 = 0.08, n.s.). Also, the quality of experimental and control territories was the same during the period without and with supplementary feeding (paired-sample t-test; experimental territories: t_4 = 0.76, n.s.; control territories: t_3 = 0.52, n.s.). From January 1989 to August 1990, the breeding pairs remained the same, apart from one. Before the start of supplementary feeding, one pair, consisting of yearling birds, occupied a vacant experimental territory after the death of the previous pair. Breeding success increased significantly with the age of the breeding birds (J. Komdeur, unpubl.). Therefore, if breeding success was significantly higher in the experimental territories with supplementary feeding, this could not be ascribed to age effects. The internal control used in this study (comparing reproduction without and with supplementary feeding on the same territory) is an explicit matched-pairs control for territory quality and pair formation.

RESULTS

Ecology of the Seychelles Magpie Robin population

Feeding ecology

On average, Magpie Robins spent 34% (n = 16) of the daytime foraging. There was no significant difference between the sexes (mean percentage foraging male *v* female [nonmoulting and nonbreeding]: 33% [n = 8] *v* 35% [n = 8]; Wilcoxon test: z = 1.19, n.s.). Therefore data from both sexes were combined in further analyses. Breeding, nonmoulting birds spent more time foraging than nonbreeding, nonmoulting birds (mean: 58% [n = 12] *v* 34% [n = 16];

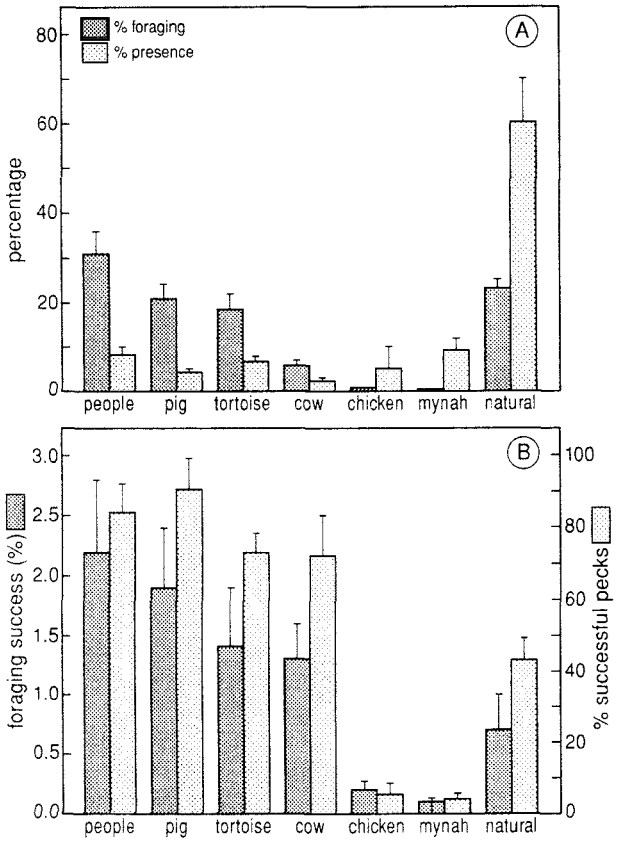

Figure 4. Significance of presence of plantation workers and animals: (a) for the time spent foraging by adult Seychelles Magpie Robins within 2.5 m of each category (percentage of foraging time per category [total: 1214 h] *v* percentage of their presence in Magpie Robin territories during the observation period [mean 25-m × 25-m squares/territory ± s.d.: 104 ± 34]); (b) for foraging success and percentage of successful pecks (n = number of 30-s observations, total n = 7086; eight birds, each observed during nine 5-h periods [45 h]).

Mann-Whitney U-test: $U = 17.0$, $P < 0.001$). Because foraging was influenced by the breeding stage of the robin, comparisons between foraging and territory quality were made using only data from birds currently not breeding and, as a precaution, nonmoulting birds.

Over 94% of all feeding records (n = 4013) were from herb-free areas of bare earth or leaf litter, mainly in cultivated plots and woodland. Most prey were invertebrates (96%; n = 2024) inhabiting the upper layers of soil and leaf litter (insects: 55%, worms 20%, centipedes/millipedes: 11%, other: 10%). The remainder of the food (4%) consisted of skinks, geckos and fruits. Most foraging (76%) took place close to plantation workers, Giant Tortoises and domestic animals (Fig. 4a). Weeding, mowing, uprooting and grazing disturb the soil surface and thereby increase access to invertebrates. On average, foraging success (±s.d) and percentage of successful pecks close to people and animals were significantly higher than under natural circumstances (1.68 ± 0.46 *v* 0.70 ± 0.30; $t_{7011} = 94$, $P < 0.001$; mean successful pecks: 80% *v* 43%; $\chi^2_1 = 999$, $P < 0.001$; Fig. 4b). Foraging close to Domestic Hens and Indian Mynahs resulted in reduced foraging success ($t_{2466} = 12.4$, $P < 0.001$) and a lower percentage of successful pecks ($\chi^2_1 = 35.9$, $P < 0.001$; Fig. 4b) because they fed on almost the same prey as Magpie Robins (dietary overlaps were 79% and 74%, respectively).

Breeding biology

Breeding parameters are shown in Table 1. Only females built nests, which on average took 10 days. The nest was a simple cup of dry grass and coconut fibre. Clutch size was always one, as in 1977–1978 (n = 12; Watson *et al.* 1992). The female incubated alone, and it was mainly the male who guarded the nest from predators. Incubation took 17–22 days, and the young left the nest after 18–20 days. Both parents fed the young, but on average the female fed them 2.5 times as often as the male throughout the period of

Table 1. *Breeding biology and performance by male and female Magpie Robins. Statistical significance of comparisons determined by Wilcoxon test (percentage data) or two-tailed paired-sample* t*-test (*n *= number of observations or individuals)*

Breeding biology	Mean ± s.e.		n	
Days for nest building	10.0 ± 0.9		8	
Clutch size	1.0 ± 0.0		9	
Days for incubation	18.8 ± 0.56		9	
Days until fledging	19.3 ± 0.42		4	
Weeks to independence	11.3 ± 1.16		8	
Months in natal territory	9.8 ± 0.73		10	
Breeding performance	**Female**	**Male**	**n**	**P**
Nest building frequency (per hour, ±s.e.)	1.4 ± 0.2	0.0 ± 0.0	14	<0.001
% incubating (±95% c.l.)	44 (18–72)	0 (0–1)	20	<0.001
% nest guarding (±95% c.l.)	2 (0–6)	32 (4–71)	20	<0.001
Total food delivery frequency to young (per hour, ±s.e.)	6.6 ± 0.8	2.6 ± 0.4	9	<0.005

Table 2. *Breeding performance by Magpie Robins in 1977–1979, 1981–1982 and 1988–1990 in five territories (nos. 3/4, 5, 9, 11, and 12) and in 1988–1990 in nine territories. Data used from Watson (1978) and Todd (1982). Values presented are means ± s.d. Statistical significance of comparisons determined by χ^2 contingency analysis (percentage data) or paired-sample* t*-test*

Productivity	1988–1990 (n = 9)	1977–1979 a (n = 5)	1981–1982 b (n = 5)	1988–1990 c (n = 5)	P a v b	P a v c	P b v c
Annual nest building attempts							
Per territory	1.67 ± 1.20	4.60 ± 3.38	3.47 ± 0.65	1.74 ± 1.07	n.s.	n.s.	n.s.
Total	29	23	13	18			
% nests with clutch	93.1	87.0	76.9	83.3	n.s.	n.s.	n.s.
Annual number of nests with clutch							
Per territory	1.47 ± 0.92	4.00 ± 2.09	2.67 ± 0.84	1.42 ± 0.86	n.s.	<0.03	<0.05
Total	27	20	10	15			
% hatching success	59.3	65.0	80.0	53.3	n.s.	n.s.	n.s.
Annual number of nests with nestling							
Per territory	0.77 ± 0.72	2.60 ± 1.82	2.13 ± 0.66	0.74 ± 0.63	n.s.	<0.05	<0.05
Total	16	13	8	8			
% nestlings fledged	56.3	76.9	75.0	75.0	n.s.	n.s.	n.s.
Annual number of fledglings							
Per territory	0.46 ± 0.43	2.00 ± 1.41	1.60 ± 0.54	0.46 ± 0.41	n.s.	<0.05	<0.05
Total	9	10	6	6			
% of fledglings reaching independence	88.9	70.0	83.3	83.3	n.s.	n.s.	n.s.
Annual number of independent young							
Per territory	0.41 ± 0.40	1.40 ± 0.89	1.33 ± 0.86	0.46 ± 0.41	n.s.	<0.03	<0.05
Total	8	7	5	5			
% young reaching one year of age	62.5	42.9	60.0	80.0	n.s.	n.s.	n.s.
Annual number of yearlings							
Per territory	0.26 ± 0.32	0.60 ± 0.89	1.06 ± 0.53	0.37 ± 0.34	n.s.	<0.05	<0.05
Total	5	3	3	4			

dependence. The young became independent of parental feeding between 9 and 18 weeks after hatching. From 1988 to 1990, only 17% of nesting attempts (n = 29) resulted in a 1-year-old young. Throughout the study period, there were two instances of attempted breeding by birds aged 11–14 months. Magpie Robins are therefore assumed to be reproductively mature by this age. Once the young became a year old, all but one (n = 12) were expelled from their natal territories. The sex ratio of yearlings did not differ from 1:1, but the sample (n = 12) was small.

Mean number of prey items in the first 5 cm of the soil was 16 times higher than in the 5 cm of leaf litter (mean [±s.e.]/133 cm^2: 0.96 ± 0.04 *v* 0.06 ± 0.05; paired-sample t-test: t_{18} = 12.2, $P < 0.001$). The number of nest building attempts corresponded significantly with monthly rainfall (Spearman correlation: $r_{17} = 0.60$, $P < 0.005$) and with peaks of soil invertebrates 1 month later ($r_{17} = 0.53$, $P < 0.005$) but not with peaks of leaf litter invertebrates ($r_{17} = 0.10$, n.s.). One month is not only the time lag between the amount of rainfall and soil invertebrate abundance but also the time between nest building and hatching. None of the other combinations of monthly prey availability, rainfall and nesting activity was significant. By responding to an increase in rainfall, Magpie Robins can time their breeding efforts so that food is at a maximum when the young hatch.

Decline of the Magpie Robin population

The total Magpie Robin population declined from 38–41 birds in 12–13 territories in 1977–1978 to 21–24 birds in 9 territories in 1981–1982 and 17–21 birds in 8–9 territories in 1988–1990 (Fig. 2). This was due not to lower annual adult survival rates (83% [33 bird-years], 84% (26), 81% (42), respectively) but to a significant decline in recruitment over the whole island. Mean numbers of yearlings present on the island were 10.8, 0.5 and 2.3, respectively, in the 3 periods. Up to 1982, feral Cats were responsible for this decline. The annual production of offspring per territory in 1977–1978 was the same as in 1981–1982 but showed a significant decline thereafter (Table 2). This was due mainly to the much lower number of nests in 1988–1990 compared with the previous periods. Mean number of nest building attempts per territory,

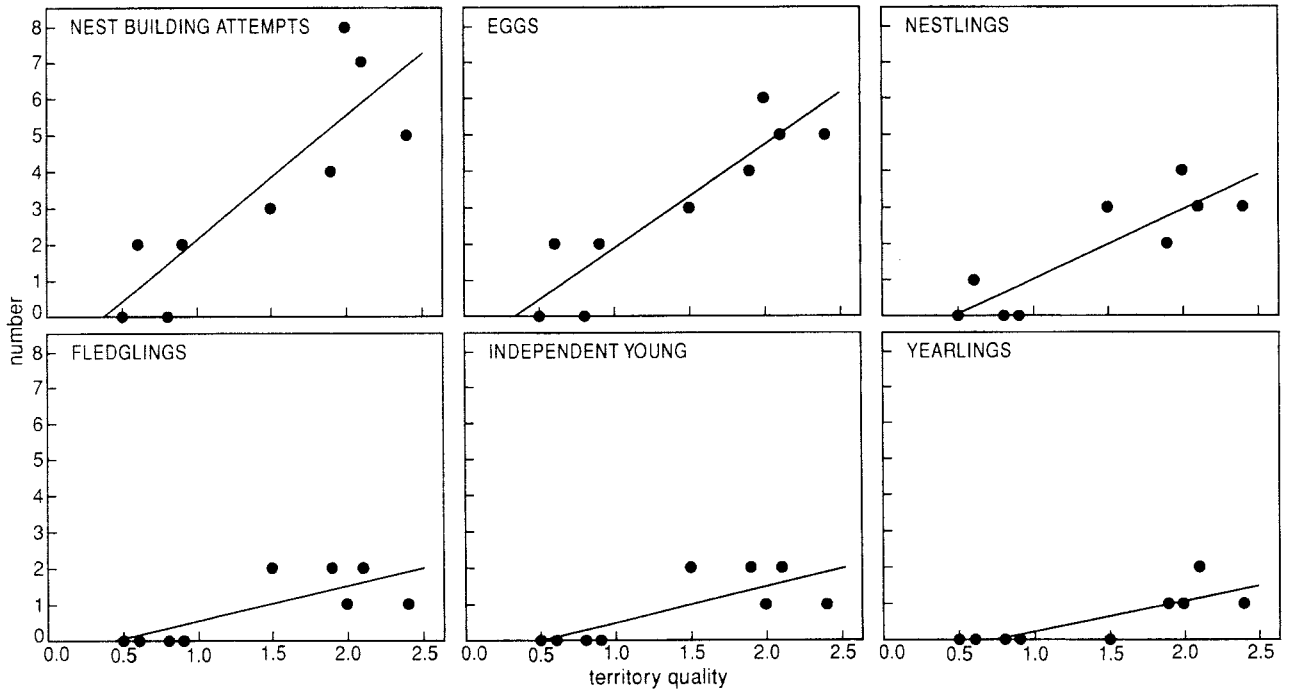

Figure 5. Reproductive success of Magpie Robin pairs in relation to mean monthly territory quality (t), measured from June 1988 to December 1989. (a) Nest building attempts = 3.39t − 1.31; $r_7 = 0.85$, $P < 0.005$; (b) Eggs = 2.80t − 0.89, $r_7 = 0.91$, $P < 0.001$; (c) Nestlings = 1.91t − 0.89, $r_7 = 0.87$, $P < 0.005$; (d) Fledglings = 1.14t − 0.60, $r_7 = 0.81$, $P < 0.01$; (e) Independent young = 0.99t − 0.50, $r_7 = 0.76$, $P < 0.02$; (f) One-year-old young = 0.82t − 0.59, $r_7 = 0.80$, $P < 0.01$.

hatching and fledging success and survival from fledging to independence and to 1 year of age were not significantly different for the three periods (Table 2). Given an annual recruitment into the adult population of 2.3 birds, and a mean population size of 18.7 adult birds during 1988–1990, the recruitment was insufficient to compensate for the annual adult mortality of 19% (loss of 3.6 birds). The population was declining.

Factors responsible for the decline of the Magpie Robin

Territory quality

The main difference in territory quality was caused by differences in food density and not by differences in territory size. Over the period June 1988–December 1989, within-territory variation in food abundance was smaller than between-territory variation ($F_{7,144} = 131$, $P < 0.01$). Over the same period, variation within and between territory sizes was similar ($F_{7,144} = 2.0$, n.s.). This means simply that some territories (and some parts of the island) were better for Magpie Robins than others. A multiple comparison test for territory quality showed five subsets of territories (Duncan's multiple range test, $P < 0.01$). The subsets, ordered from high to low quality, were (1/2, 3/4), (5, 9), (8/10), (6/13) and (11, 12). These quality differences between territory groups remained stable over time.

Surprisingly, the better territory quality, the lower the foraging efficiency of Magpie Robin breeding pairs ($r_6 = -0.72$, $P < 0.05$). Birds which held high-quality territories spent less time foraging ($r_6 = -0.92$, $P < 0.001$) but still had higher total foraging success ($r_6 = 0.94$, $P < 0.001$). Adult birds (nonmoulting and nonbreeding) spent significantly more time foraging in 1989 than did birds in 1978 in the same territories (mean percentage foraging [±95% c.l.]: 27.1 [0.0–60.5; $n = 8$] *v* 10.4 [0.0–38.1; $n = 9$]; $t_{15} = 3.97$, $P < 0.002$). Also, the mean feeding rate (±s.e.) was significantly lower in 1989 than in 1978 (1.44 ± 0.04 [$n = 8$] *v* 2.55 ± 0.23 [$n = 9$]; $t_{15} = 3.21$, $P < 0.001$). On average, foraging activity in 1989 was 3.5 times lower than in 1978, suggesting that territory quality had declined markedly.

The positive effect of territory quality on foraging efficiency presumably affected the amount of energy which could be allocated to reproduction without incurring additional survival costs. Correlations between territory quality and breeding parameters were all positive and significant (Fig. 5). Magpie Robin pairs occupying higher quality territories built more nests and produced more eggs, nestlings, fledglings, independent young and yearlings. Significant differences occurred from the egg stage to the fledging stage (Fig. 5). Of all the clutches laid, only 59% resulted in nestlings (Wilcoxon test: $z = 2.20$, $P < 0.05$), and of the nestlings produced, only 56% fledged successfully ($z = 2.03$, $P < 0.05$; Table 2).

Forward multiple regression showed that territory quality (measured at the time when the egg was present) and mean foraging distance (distance between the nest and foraging areas) both had significant influences on time spent incubating by the female and on time spent nest guarding by the male. Territory quality explained most of the variance. The lower the territory quality, the less time was spent incubating by the female ($r^2_9 = 0.88$, $P < 0.02$) and guarding the nest by the male ($r^2_9 = 0.87$, $P < 0.01$; Fig. 6a). The larger the foraging distance (controlled for territory quality effects), the less time was spent incubating ($r^2_9 = 0.60$, $P < 0.04$) and nest guarding ($r^2_9 = 0.80$, $P < 0.02$; Fig. 6b). As a consequence, the total percentage of time spent by at least one bird near or on the nest was reduced and the egg had a lower probability of hatching (Fig. 6c).

Nest trees and nest disturbance

All nesting attempts by Magpie Robins were either in holes of rotten trees or in crowns of Coconut trees *Cocos nucifera*. If trees with holes were present in territories (even one or two trees), Magpie Robins built significantly more nests in these trees than in Coconut trees, which were abundant (mean use: 93% *v* 7% [$n = 16$]; $\chi^2_1 = 12.3$, $P < 0.001$). Because rotten tree holes were scarce, birds had to fly long distances between the nest site and feeding areas, which in itself contributed to nest failure.

Sometimes when Magpie Robins were nesting in Coconut trees, an Indian Mynah pair started nesting in the same tree. The mynahs were not seen to interfere directly with the Magpie Robin nest, but their close proximity was enough to disturb the Magpie Robins. Immediately after the mynahs arrived, the nest-building female robin abandoned her nest and started a new nest somewhere else ($n = 9$). If mynahs arrived during incubation, the female robin left the nest. The percentage of incubation (±95% c.l.) by the female disturbed by mynahs was significantly lower than that by the same female without disturbance (1% [c.i. 0.0–2.2%] *v* 49% [33.9–64.5%]; $n = 4$, Wilcoxon test: $z = 1.83$, $P < 0.04$). Mean hatching successes with and without disturbance were 0 and 75%, respectively.

Because of the lack of suitable areas for establishing a territory from June to December 1989, five young adults became floaters in high-quality areas. They caused disturbance to four breeding pairs. During the corresponding period from June to December 1988 without floaters, mean production by these pairs was the same as that of other pairs (1.25 ± 0.25 nestlings [$n = 4$] and 0.50 ± 0.50 nestlings [$n = 4$], respectively; $t_6 = 1.90$, n.s.). With floaters present, pairs produced no nestlings (paired-sample *t*-test: $t_3 = 5.00$, $P < 0.01$), but the number of nestlings produced by pairs without floaters was the same (0.50) as during the corresponding period in 1988. The number of nests surviving to successive stages of breeding, in periods with and without disturbance by floaters, showed that most failures occurred between egg laying and hatching (Table 3). Total incubation time by the same female disturbed by a floater

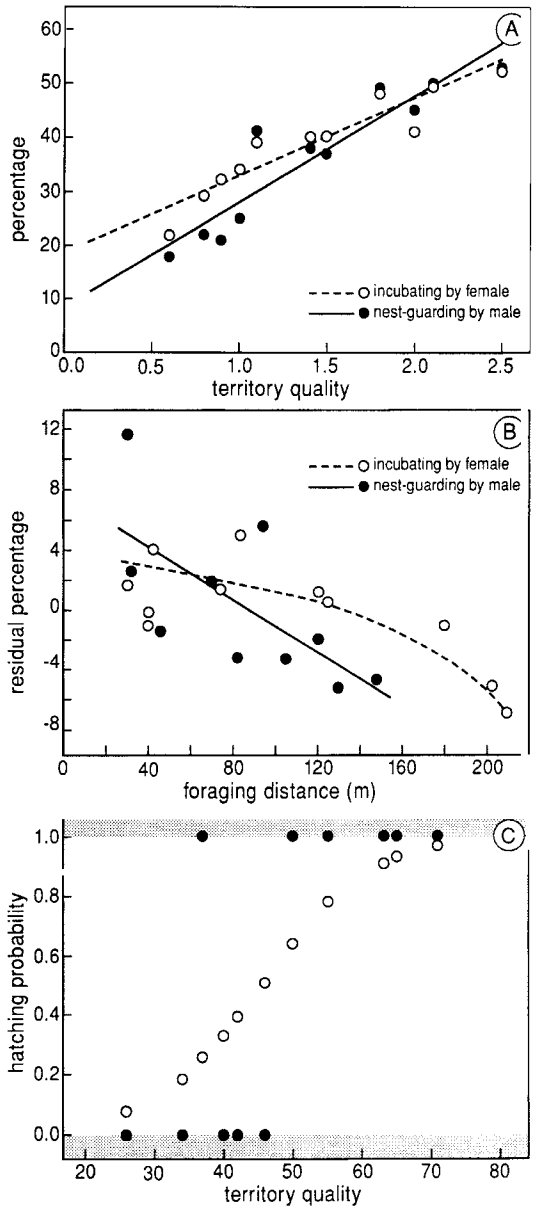

Figure 6. Percentage of time spent in incubation by the female (F) and in nest guarding by the male (M) Magpie Robin in relation to (a) territory quality at breeding (t); (b) foraging distance (fd) from the nest; (c) percentage of time spent by Magpie Robin pairs near (<2.5 m) or on the nest in relation to hatching probability. Values presented in (b) are adjusted means calculated using multiple regression analysis in which the effect of territory quality was controlled (in each set of data a bird appears only once). Values presented in (c) are predictor variables calculated using logistic regression analysis. (a) % incubation = 0.16t ± 17.94, $r_9 = 0.93$, $P < 0.001$; % nest guarding = 0.21t + 0.07, $r_9 = 0.93$, $P < 0.001$; (b) % incubation (adjusted for t effects) = −0.001fd + 0.527, $r_9 = 0.66$, $P < 0.05$; % nest guarding (adjusted for t effects) = −0.003fd + 0.60, $r_9 = -0.83$, $P < 0.001$; (c) $D_1 = 4.77$, $P = 0.029$; probability of hatching = $1/(1 + e^{-z})$; $z = 11.33$(% time near or on the nest) − 5.36.

Table 3. *Breeding performance of four Magpie Robin pairs without (June–December 1988) and with (June–September 1989) presence of Magpie Robin "floaters" (±s.d. or ±95% confidence limits for percentage data). Mean monthly territory quality during both periods is given. Statistical significance of comparisons determined by one-tailed Wilcoxon test (percentage incubation, n = number of pairwise [mean values of same female] observations) or χ^2 contingency analysis (rest of percentage data), one-tailed paired-sample t-test*

Productivity	Without floaters	With floaters	*P*
Nest building attempts			
Per territory	1.75 ± 0.50	1.50 ± 0.58	n.s.
Total	7	6	
% nests with clutch	85.7	83.3	n.s.
Nests with egg			
Per territory	1.60 ± 0.58	1.60 ± 0.28	n.s.
% incubation (n = 4)	46 (26–65)	1 (0–5)	<0.001
Total	6	6	
% hatching success	83	0	<0.03
Nests with nestling			
Per territory	1.25 ± 0.50	0.0 ± 0.0	<0.01
Total	5	0	
Number of fledlings			
Per territory	1.25 ± 0.50	0.0 ± 0.0	<0.01
Total	5	0	
Mean monthly territory quality	1.48 ± 0.35	1.82 ± 0.14	<0.01

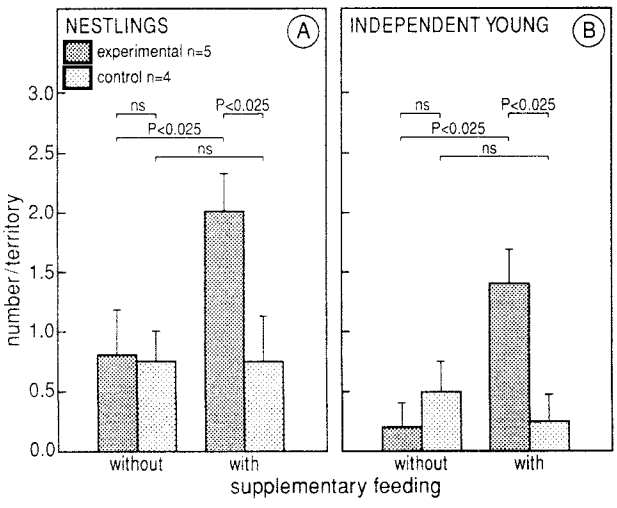

Figure 7. Reproductive success of Magpie Robin pairs in experimental (with supplementary feeding) and control territories during an 8-month period (January–August) without (1989) and with (1990) supplementary feeding. Reproductive success measured as (a) the number of nestlings; (b) the number of independent young produced per territory. Means, standard errors and sample sizes are shown. *P*-values for differences between experimental and control territories were determined by one-tailed Mann-Whitney *U*-test, and for without and with supplementary feeding by one-tailed paired-sample *t*-test.

was significantly lower than without disturbance (Table 3). During incubation the breeding pair spent a lot of time inspecting the territory and chasing intruders, which resulted in less time for incubating and a higher proportion of nest failures (Table 3). Mean monthly territory quality, which was correlated with reproductive success, was significantly higher during the 7-month period with disturbance by floaters than during the corresponding period in 1989 without disturbance (Table 3).

Supplementary feeding and breeding success

Mean production of nestlings and independent young for experimental and control units was the same during the 8-month period before the experiment (Fig. 7). With supplementary feeding, there was a significant increase in reproductive success of the experimental group compared with the control group, but reproductive success of the control group was the same as before (Fig. 7).

The Magpie Robin pairs in the poorest territories (nos. 11 and 12) both responded immediately to the increase in food availability by building a nest and by raising a chick to 1 year of age. Both young were the first recorded from these territories since 1977 (Watson 1978, Todd 1982, C. Warman & S. Warman, unpubl., V. Laboudallon, unpubl., A.J.E. Seddon & M.C. Garnett, unpubl., J. Komdeur, unpubl.). Supplementary feeding did not affect the number of nest attempts, percentage and number of nests with an egg or the percentage of independent young surviving to 1 year of age

Table 4. *The effect of supplementary feeding on breeding performance (±s.d. or ±95% confidence limits for percentage data) by five Magpie Robin pairs. Statistical significance of comparisons determined by one-tailed Wilcoxon test (percentage incubation and nest guarding, n = number of pairwise [mean values of same female] observations) or χ^2 contingency analysis (rest percentage data), one-tailed paired-sample t-test or one-tailed t-test*

Productivity	Without feeding $n = 5$	With feeding $n = 5$	P
Nest building attempts			
Per territory	1.80 ± 0.84	2.00 ± 0.71	n.s.
Total	9	10	
% nests with egg	88.9	100	n.s.
Nests with egg			
Per territory	1.60 ± 0.75	2.00 ± 0.69	n.s.
Mean week of first egg laid	9.0 ± 3.39	4.2 ± 1.30	<0.05
% incubation	26 (16–39)	52 (38–68)	<0.03
% nest guarding	25 (14–37)	44 (35–52)	<0.03
Total	8	10	
% hatching success	50.0	100	<0.05
Nests with nestling			
Per territory	0.80 ± 0.84	2.00 ± 0.71	<0.005
Food provision rate per nestling (per hour)	2.7 ± 0.04 ($n = 5$)	3.9 ± 0.3 ($n = 11$)	<0.001[a]
Fledgling weight (at 17 days of age)	56.1 ± 1.1 ($n = 4$)	61.2 ± 1.2 ($n = 6$)	<0.001[a]
Total	4	10	
% nestlings reaching independence	25	70	n.s.
Number of independent young			
Per territory	0.20 ± 0.45	1.40 ± 0.55	<0.005
Total food provision rate per fledgling (per hour)	1.5 ± 0.3 ($n = 3$)	3.8 ± 0.8 ($n = 7$)	<0.001[a]
Period of parental care (weeks)	11 ± 1.4 ($n = 3$)	17 ± 2.9 ($n = 7$)	<0.01[a]
Total	1	7	
% independent young reaching 1 year of age	100	78	n.s.
Number of yearlings			
Per territory	0.20 ± 0.45	1.00 ± 0.00	<0.01
Total	1	5	

[a] One-tailed *t*-test.

(Table 4). Supplementary feeding provided important benefits: it advanced laying date, made more time for incubation and nest guarding, which improved hatching success, and produced higher food provision rates to nestlings and fledglings, higher fledging weights and a longer period of parental care (Table 4). Thus, with intensive supplementary feeding, recruitment can be improved fivefold, and, potentially, each year 11.5 (5 × 2.3) recruits will become available to the population.

DISCUSSION

Recovery plan for the Magpie Robin

The Seychelles Magpie Robin has a one-egg clutch, which, when combined with low fledging success, leads to low reproductive productivity. This does not need to present a conservation management problem if the constraints on reproduction are only temporary. Magpie Robins are long-lived (the oldest bird recorded was more than 14 years old, and mean adult life expectancy is 4.3 years) and therefore can tolerate periods of low recruitment. In contrast, they are particularly vulnerable to factors which lead to increased adult mortality or prolonged reduction in recruitment. The reduced recruitment began to have an effect in 1980, and a recovery plan was designed by BirdLife International in 1989 and implemented in September 1990. The aim was to increase the Magpie Robin population on Fregate and reestablish breeding populations on other islands within Seychelles.

On Fregate, tree holes for nest sites are scarce. Alternative nests in Coconut crowns are vulnerable to disturbance and predation, as many crowns have abundant reptiles. Open-front nestboxes have been erected near rich feeding areas, and they have been readily accepted by Magpie Robins (McCulloch 1994). Nest predation and interference by skinks and snakes were reduced by a simple nest guard consisting of plastic sheeting clamped around the trunk of the

nest tree. Nestboxes were successful. Over 51% of eggs (n = 66, 1992–1994; McCulloch 1994) produced fledged young compared with 33% (n = 29, 1988–1990) under more natural conditions. The numbers of Indian Mynahs (who compete for nest sites and food) were effectively reduced from 500–600 to *c.* 50 birds by shooting (McCulloch 1994).

Magpie Robins forage mostly in cultivated plots and in woodlands because of high prey density in those areas. The total area of these "core foraging areas" on the island is 21.5 ha or 10.2% of the potential suitable area. Until 1990, this area supported the entire world population of Magpie Robins. Much of the woodland contained a dense shrubby understorey of nonnative vegetation (principally Coconut and Cocoplum *Chrysobalanus icaco*) that blanketed the ground and deterred the Magpie Robins from foraging. Improving the feeding conditions by removal of the scrubs in an occupied territory where breeding had not occurred in the last 10 years resulted in the production of one young (McCulloch 1994). To date, approximately 10 ha has been cleared of scrubs and planted with native trees (McCulloch 1994). Because of the slow growth rate of the trees, newly established woodland will be unlikely to benefit Magpie Robins for at least 10 years from the start of tree planting.

Feeding conditions can also be improved by increasing the numbers of free-ranging pigs and Giant Tortoises. In contrast, free-ranging Cows and hens have negative effects: the former by eating tree seedlings and the latter by competing for food with Magpie Robins. However, since 1990, Cows have been tethered and hens have been kept in coops. The response of the Magpie Robin population to these management changes was slow but positive. By the end of 1992, Magpie Robin numbers had risen from 22 to 27 (Gretton 1992).

Following the intensification of supplementary feeding since early 1993, the population had grown to 44 individuals by the end of April 1994 (N. McCulloch, pers. comm.). Supplementary feeding at various places has assisted the repartitioning of one territory (territory 1/2 into 1 and 2) and the reestablishment of two territories (nos. 7 and 14; Fig. 2). With intensive supplementary feeding, each year, 11.5 potential breeding recruits will be available to the population. Of these, 5.3 birds are required to compensate for adult mortality. As the number of territories has not increased considerably since 1981 and is not expected to do so in the short term, the 6.2 potential Magpie Robin breeders produced each year can be regarded as a "surplus" and used for translocation to other islands.

Justification for Magpie Robin translocation

A single population will always be vulnerable. With the current carrying capacity of 11 territories, the effectiveness of increasing the carrying capacity is limited because there is not enough suitable habitat to support more birds. Translocations of birds will take some of the population pressure,

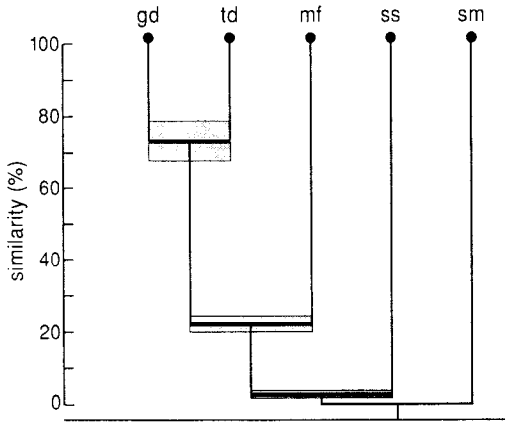

Figure 8. Phenogram of UPMGA clustering (see Appendix) showing similarities (O ± 95% confidence limits (shaded)) in feeding ecology between landbird species on Aride Island (September 1987–March 1988). Similarity varies from 0 (no similarity) to 100% (identical feeding patterns). Ss, Seychelles Sunbird; mf, Madagascar Fody; gd, Ground Dove; td, Turtle Dove; sm, Seychelles Magpie Robin.

caused by floaters, off Fregate. Thus, in order to give the species the security of more breeding groups, lest some ecological disaster should befall the parent population, Collar and Stuart (1985) and Komdeur *et al.* (1989) recommended the establishment of populations on other islands. While suitable habitat, including adequate invertebrate food supplies, was clearly a priority, the absence of cats and rats and a complete ban on chemical pesticides were considered conditional, and some form of sustained commitment to conservation management was desirable. Of the islands known to have supported Magpie Robins before and fulfilling these criteria, Aride was selected. It is a nature reserve managed and owned by the Royal Society for Nature Conservation (RSNC). On Aride, the extension of native woodland is well under way because of a tree planting program started in 1987.

Suitability of Aride Island and transfer of Magpie Robins

On Aride, the Magpie Robin fills an open niche because of lack of competition for food with the other landbird species present (Fig. 8). Although the Seychelles Warbler was not present at that time, it was expected that the Magpie Robin would not compete with the warbler since the latter is purely insectivorous, taking 98% of its insect food from leaves (Komdeur 1994).

Between May 1989 and April 1990, mean monthly soil invertebrate density of Aride was the same as that of Fregate under comparable vegetation types (mean monthly invertebrates of seven sites combined [±s.d.]: 12.0 ± 2.7 *v* 12.2 ± 3.9; n = 12, n.s.). On both islands, the densities of centipedes and millipedes were the same (Aride: 0.52 ± 0.19, Fregate: 0.44 ± 0.12; n = 12; Komdeur *et al.* 1989). However, Fregate held higher densities of earthworms (0.79

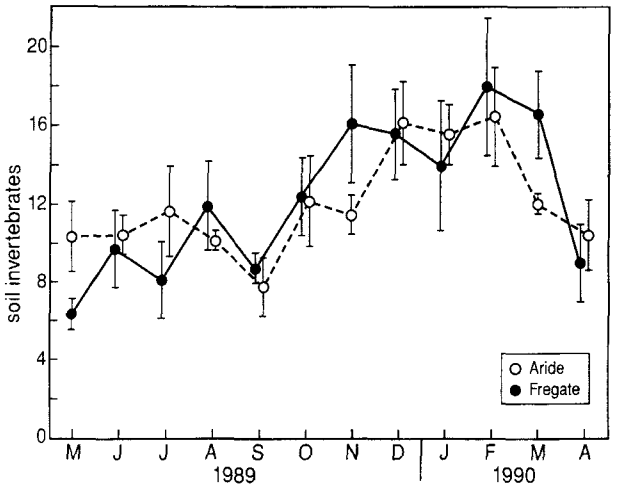

Figure 9. Monthly island quality (based on prey invertebrates available per unit area) of Aride Island and Fregate Island (May 1989–April 1990).

± 0.15 *v* 0.38 ± 0.11, $n = 12$), whereas Aride held more other invertebrates (1.66 ± 0.28 *v* 0.38 ± 0.07, $n = 12$; Komdeur *et al.* 1989). The seasonal pattern of soil invertebrate densities on both islands was the same ($r_{10} = 0.70$, $P < 0.01$; Fig. 9). On average, prey density in random samples was 2.3 times higher on Fregate (mean: 21.0 ± 5.6 *v* 9.1 ± 2.9). On Aride, geckos, skinks and alternative food sources (e.g. seabird eggs and fish) for Magpie Robins were more abundant than on Fregate (Komdeur *et al.* 1989).

In order to ensure future survival, one robin pair needs to produce at least two recruits during its estimated lifetime of 4.3 years. In other words, one territory should produce 0.47 yearlings per year. The minimum territory quality to enable this is 1.29 (yearlings = 0.82t − 0.59; Fig. 5). Given a minimum territory size of 5 ha (80 grids), a territory should have a prey density of at least 103 (1.29 × 80) prey invertebrates per 5 ha. This indicates that Aride Island, with mean island quality of 1124, could potentially hold 10–11 territories (Komdeur *et al.* 1989).

A surplus of males on Fregate in 1992 provided an opportunity to test the current suitability of Aride for the species. In April 1992, two young males were successfully transferred to Aride Island and have been continuously monitored (Gretton 1992). To date, the 1992 translocations have proved successful, showing that Aride can support Magpie Robins. In February 1994, a female was successfully transferred and formed a pair bond with one of the males immediately after release. The total Magpie Robin population in 1994 consisted of 47 birds on two islands, the highest level for 16 years.

Perspectives

The conservation activities on Fregate Island have resulted in an encouraging improvement in productivity and survival in the Seychelles Magpie Robin. Supplementary feeding may allow more Magpie Robins to be accommodated on the island than would otherwise be possible, but this is not sustainable in the long term. The creation of suitable habitat by reforestation is necessary, both on Fregate and elsewhere, if the species' survival on a self-sustaining basis is to be secured.

It is believed that the recovery plan will save the Seychelles Magpie Robin from extinction. A figure of *c.* 100 individuals on at least three islands seems a reasonable target. The cross-fostering program for the Chatham Island Black Robin *Petroica ltaversi* ceased when numbers neared 100 (Merton & Butler 1993). The Black Paradise Flycatcher *Terpsiphone corvina* and the Black Parrot *Coracopsis nigra barklyi* each number less than 100 individuals, and yet neither is considered at critical risk (Collar & Stuart 1985). It is unlikely that Fregate Island could ever return to a natural state, but it is possible to establish natural tall forest on one-third of the island and to build up tortoise numbers for increasing feeding conditions for Magpie Robins. Such an island could support 15 Magpie Robin territories (50–60 individuals). Populations on at least two other islands should be established, which should also be managed in as natural a way as possible. At present, few of the granitic islands of the Seychelles present realistic opportunities for further translocations because of the presence of rats and cats. However, it may be possible to remove predatory mammals from some otherwise suitable islands. Population and habitat monitoring will always be needed, as will vigilance that exotic predators are not introduced. As with the Seychelles Warbler (Komdeur 1994), it is hoped that it will be possible to return this species from the brink of extinction and to reclassify it as "Out of Danger".

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REFERENCES

Collar, N.J. & Stuart, S.N. 1985. Threatened Birds of Africa and Related Islands. ICBP/IUCN Red Data Book, Part 1. Cambridge: International Council for Bird Preservation.

Gretton, A. 1992. Ecology of the Seychelles Magpie Robin *Copsychus sechellarum*. Proc. Pan-Afr. Orn. Congr. VIII: 165–172.

Komdeur, J. 1994. Conserving the Seychelles Warbler *Acrocephalus sechellensis* by translocation from Cousin Island to the islands of Aride and Cousine. Biol. Conserv. 76: 143–152.

Komdeur, J., Komdeur, M.D., Castle, G. & Mileto, R. 1989. Proposed Translocation Project for the Seychelles Magpie Robin *Copsychus sechellarum* from Fregate Island to Aride Island. ICBP Unpubl. Report. Cambridge: International Council for Bird Preservation.

McCulloch, N. 1994. Rescuing the Seychelles Magpie Robin. RSPB Conservation Review 8: 88–94.

Merton, D. & Butler, D. 1993. The Saving of the World's Most Endangered Bird. OUP New Zealand. Oxford: Oxford University Press.

Penny, M. 1982. The Birds of Seychelles and the Outlying Islands. London: Collins.

Todd, D.M. 1982. ICBP Emergency Project: Seychelles Magpie Robin and cat eradication on Frégate Island. ICBP Unpubl. Report. Cambridge: International Council for Bird Preservation.

Watson, J. 1978. WWF Project 1590 Final Report 1(a): The Seychelles Magpie Robin *Copsychus sechellarum*. WWF Unpubl. Report. Morges: World Wildlife Fund.

Watson, J. & Trowbridge, B.J. 1979. WWF Project 1590 Final Report 2(a): The Seychelles Magpie Robin *Copsychus sechellarum*. WWF Unpubl. Report. Morges: World Wildlife Fund.

Watson, J., Warman, C., Todd, D. & Laboudallon, V. 1992. The Seychelles Magpie Robin *Copsychus sechellarum*: Ecology and conservation of an endangered species. Biol. Conserv. 61: 93–106.

Wilson, J. & Wilson, R. 1978. Observations on the Seychelles Magpie Robin *Copsychus sechellarum*. Bull. Br. Ornithol. Club 98: 15–21.

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APPENDIX

Percentage of feeding observations of five landbird species (for abbreviations see Fig. 8) on Aride Island, classified by plant species, part of plant, feeding height and food item taken (si, skink or soil invertebrate; i, insect; fs, fruit or seed; n, nectar; September 1987–March 1988; n *= number of observations). The overlap between bird species i and j (O_{ij}) was calculated as the sum of the least shared percentage (P_{min}) in each feeding category (for example, the sum of the least shared percentages for feeding observations of the Ground Dove and the Turtle Dove is 0.0% + 31.5% + 0.0% + 0.0% + 41.4% + 0.0% + 0.0% + 0.0% + 0.0% = 72.9%)*

Plant part	Height (m)	Food item	*Pisonia*					*Morinda*					Other trees					Herbs				
			ss	mf	gd	td	sm	ss	mf	gd	td	sm	ss	mf	gd	td	sm	ss	mf	gd	td	sm
		si					20.6					9.5					58.7					
		i																			3.4	
		fs									5.1				31.5	39.3			6.2	41.4	43.3	
Leaf	0–4	i	17.1					0.6					15.9					2.4		0.6		
	4–8	i	7.1					0.6					6.5									
	>8	i	1.8										1.8									
Branch	0–4	i	2.9					1.8					2.4					1.2	4.6	0.6		
		fs																	63.9	25.9		
	4–8	i	1.2														4.8	1.2				
	>8	i											1.8				6.4					
Flower	0–4	n						4.1	0.8				1.8					21.2				
	4–8	n						4.1	3.9													
Fruit	0–4	i						0.6										2.4	1.5			
		fs												4.6					13.1		5.6	
	4–8	i														3.4						
		fs												1.5								
n			51	0	0	0	13	20	12	0	9	6	51	16	51	76	44	48	232	111	93	0